TITLE OF THE INVENTION

Communication System, Sender and Receiver

FIELD OF THE INVENTION

The present invention relates to a communication system and more particularly to a communication system via high noise transmission lines of low-voltage power such as an electric wire and its sender and receiver.

BACKGROUND OF THE INVENTION

Such narrow-band noises as distortion and impulse noise in transmission lines are often too great to overlook in the transmission systems. In such transmission systems, a diffusion data transmission technique has been used as useful means to combat those noises in the past. The diffusion data transmission technique comprises the sender which diffuses data to send via a transmission line and the receiver which inversely diffuses data received.

The data transmission system based on that conventional diffusion data transmission is described by the following example of the data transmission system using the existing electric power line, that is, low-tension power line of a 100-volt a.c., 50/60 Hz.

Fig. 15 is a block diagram showing an example of the conventional system of the direct diffusion technique for sending data via the electric power line.

In Fig. 15, a sender 100 and a receiver 200 are connected to each other via a transmission line 300.

The sender 100 is provided with a mixer 110, a pseudo noise generator 111, a carrier wave oscillator 112 and an equilibrium modulator 113. The receiver 200 includes a mixer 210, a pseudo noise generator 211, a carrier wave oscillator 212, an equilibrium modulator 213 and an intermediate frequency band pass filter (IF-BPF) 214.

Diffusion signals from the pseudo noise oscillator 211 is inputted in

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the mixer 110 on the sender side as well as input data are inputted in the same. Those two kinds of signals are multiplied and inputted in the next equilibrium modulator 113. The aforesaid carrier wave oscillator 112 generates and inputs a carrier wave in the equilibrium modulator 113. The equilibrium modulator 113 then modulates the carrier wave with the signal from the mixer 110 (diffused input signal) and sends out the modulated carrier wave without the original carrier wave to the receiver 200.

In the receiver 200, the carrier wave oscillator 212 generates a carrier wave with the same frequency as of the carrier wave generated by the carrier wave oscillator 112 on the side of the sender 100, and inputs it in the equilibrium modulator 213. Meantime, the pseudo noise generator 211 produces an inversely diffused code with a phase opposite to the diffused code generated by the sender 100, and inputs it in the equilibrium modulator 213. Thereby, the equilibrium modulator 213 modulates the carrier wave outputted from the carrier wave oscillator 212 by using an inversely diffused code outputted by the pseudo noise generator 211. The modulated carrier wave is then outputted to the mixer 210. The mixer 210 multiplies a modulated signal inputted via the transmission line 300 and a modulated signal inputted from the equilibrium modulator 213, and then outputs its result to IF-BPF 214. IF-BPF 214, which means an intermediate frequency band pass filter, is a filter through which waves in the intermediate frequency band can pass.

Now, supposing that the data signal inputted to the mixer 110 carries a spectrum as shown in Fig. 16 (a), the mixer 110 diffuses the spectrum by multiplying the input data signal using the diffused code provided by the pseudo noise generator 111. A spectrum waveform of an input data signal after the diffusion is shown in Fig. 16 (b). The diffused data signal then modulates a carrier wave outputted from the carrier wave oscillator 112 at the equilibrium modulator 112 and outputs the modulated signal onto the transmission line 300. The phrase diffused code means a code with multiple bits in relation to "1" or "0" as, for example, a 31-bit code like 1111100011011101010000100101100 or

00000111001000101011110110100111.

The following is described in the case that an impulse noise (shaded area indicated in Fig 16(c)) occurs while data signals are being sent via the transmission line 300 and the receiver 200 is to receive the signals shown in Fig 16 (c).

As mentioned, the carrier wave outputted by the carrier wave oscillator 212 in the receiver 200 is modulated with the inversely diffused code given by the pseudo noise generator 211 at the equilibrium modulator 213. Furthermore, the mixer 210 diffuses the spectrum by multiplying the modulated signal and the diffused data signal obtained via the transmission line 300. The inversely diffused code is a code that the total bits of the diffused code is "1" against the inputting of "1" if the absolute OR with the diffused code is taken, (reversely, the inputting "0" brings the total bits of the diffused code to "0"), that is, the inversely diffused code is a code that the diffused code is turned round

In the multiplication performed at the mixer 210, the data signals diffused at the sender 100 will be inversely diffused but will undergo usual diffusion against the impulse noise. Therefore, the spectrum waveform of data signals after the multiplication (that is, an inverse diffusion) is as shown in Fig 16(d). That is, the data signals are recovered to the original form while the impulse signals generated in transmission are diffused instead, so that the level for the data signals gets small immediately. This way, the effect of the impulse signals upon the data signals is alleviated

Needless to say, however, in order to carry out the aforesaid inverse diffusion exactly, it is necessary to exactly synchronize the inputting in the mixer 210 of signals from the transmission line and the inputting of modulated signals from the equilibrium modulator 213.

As set forth above, the conventional system of sending data by direct diffusion technique alleviates the effects of narrow band noises such as impulse noise as well as distortion on the transmission line caused by equipment

connected to the line, (for example, the line noise occurring at the start-up of the compressor in the household refrigerator connected to the low-tension electric power line through the 100 V outlet in the house), by the processing of diffusing and inversely diffusing the spectrum as indicated in Figs. 16 (c) and 16 (d).

The technique of diffusing spectrum is described in a book entitled " Spectrum Diffusion Communication Formula" published by Jatech Publishing Co., pages 9 to 28.

The prior art system of sending data by the direct diffusion technique as just outlined is effective in removing the effects of narrow-band noises and line distortion to some extent. But in the prior art, it is impossible to completely get rid of the effects of narrow-band noises and line distortion over the full band of frequencies as in the low-tension power line. That is, in case the line noise or distortion is too strong over the level of input data signals, the conventional diffusion technique is no longer effective enough to reduce those noises or distortion.

And, since the frequencies of the aforesaid diffused code are spread over a wide band, the bandwidth occupied by the modulated signals increases. Accordingly a large number of side lobes rises over a wide band as well as a main lobe, and those side lobes consume much energy and keeps down the transmission efficiency. As mentioned, furthermore, the inverse diffusion requires the synchronizing of signals obtained from the transmission line and signals from the equilibrium modulator. This synchronizing undergoes complicated procedures and costs much when it is carried out through a fairly complicated circuit or program. In addition, the prior art is not sufficient in synchronizing accuracy and can fail to detect data.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a communication system for transmitting data at a high speed with the data quality kept high by

making good use of frequency bands which are free from the effects of narrow band noises or line distortion. It is another object of the present invention to provide a communication system which can improve transmission efficiency and accuracy through the use of a plurality of carriers with the frequencies assuming values at specific intervals.

To achieve the foregoing objects, the present invention adopts a number of means described below. And it is prerequisite that the present invention adopts a communication system in which a sender 1 and a receiver 2 are connected to each other via the transmission line. That communication system is the basis on which the present invention is built.

First, according to the above prerequisite arrangement, the basis communication system is provided with a sending signal generating means 10 as shown in Fig. 1 and Fig. 6. The sending signal generating means 10 output converted data after converting an input signal into a plurality of carrier signals assuming values at such intervals on the axis of frequency that the frequencies may not interfere with each other. If an interfering noise with any one of the plurality of frequencies arises on the transmission line, removal of only a carrier of the noise frequency would leave the communication in a good condition.

The sending signal generating means 10 is formed of a carrier signal generating means 12 for generating signals with frequencies assuming values at specific intervals, and a multiplication means 11 for sending out the input signals on the transmission line after multiplying them by the respective carrier signals and then.

A transmission line characteristics measuring means 20 is provided on the receiver 2 to find the characteristics on the transmission line, and on the basis of the results from the transmission line characteristics measuring means 20, a selection control means 40 provided to the sender 1 or the receiver 2 judges whether a noise arises on the transmission line or not.

The selection control means 40 incorporates the results in the sending

signals from the sender 1 or in the receiving signals to be inputted in the receiver 2 via the transmission line.

In other words, the selection control means 40 controls the generation of carrier signals at a carrier signal generating means 12 in the sender 1, as shown in Fig. 6 and Fig. 8, so that the selection control means 40 does not send out carrier signals with poor characteristics on the transmission line. Or decreases the ratio of carrier signals with poor characteristics on the transmission lines. Or the selection control means 40 does not pick out and commit to synthesis the carrier signals with poor transmission line characteristics in forming the signals to be received by the receiver 2 as illustrated in Fig. 1. Or the means 40 reduces the percentage in the synthesis of the carrier signals with poor transmission lines characteristics.

The transmission line characteristics measuring means 20 determines line characteristics on the basis of the absolute value of the intensity of receiving signals as shown in Fig. 3 and Fig. 7 or on the basis of the phase difference from the reference phase and inputs the results in the selection control means 40.

Still better results can be hoped for if the respective carrier signals are so arranged as not to interfere with each other or so arranged to intersect orthogonally with each other not only on the axis of frequency but also on the axis of time as shown in Fig. 13 and Fig. 14.

That is to say, it is so arranged that the sender 1 generates carrier signals by passing the input signals through a plurality of filters 52 which satisfy the orthogonal requirements both on the axis of frequency and the axis of time (double orthogonalization). On the other hand, the receiver 2 uses a plurality of filters 62 which form only the same but time-delayed with sending signals. That can form signals with a band narrow not only on the axis of frequency but also on the axis of time - the sending signals largely not subject to the effects of noises arising on the transmission line.

In that case, it is also desirable to eliminate or reduce the mixing

ratio of the carriers which flow through the transmission lines with poor characteristics.

For a plurality of types of input signals, it is, in principle, necessary to provide a plurality of sets of the sending signal generating means 10. In case the aforementioned double orthogonalization is used, it is desirable that the encoder should have a function of allocating the filters, for example, filters a to c for input A and filter d to f for input B, since an encoder is used to divide the input signals in the number corresponding to a plurality of filter.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig 1 is a block diagram showing the configuration of a communication system in a first embodiment of the present invention.

Fig 2 shows examples of spectrum waveforms of the transfer functions and data of carrier signals in the receiver in Fig 1.

Fig 3 shows a typical selection with absolute value signals of carrier signals which is carried out by a receiving signal synthesizing means in Fig 1.

Fig 4 shows a typical selection with relative phase signals of carrier signals which takes place in the selection synthesizing circuit in Fig 1.

Fig 5 shows a typical selection of carrier signals with both absolute value signals and relative phase signals which takes place in the selection synthesizing circuit in Fig 1.

Fig 6 is a block diagram showing the configuration of a communication system in a second embodiment of the present invention.

Fig 7 shows a typical selection of carrier signals with both absolute value signals and relative phase signals which takes place in the selection synthesizing circuit in Fig 6.

Fig 8 is a block diagram showing the configuration of a communication

system in a third embodiment of the present invention

Fig 9 is a block diagram showing the configuration of a communication system in a fourth embodiment of the present invention

Fig 10 shows examples of spectrum waveforms of the transfer functions and data of carrier signals in the receiver in Fig 9.

Fig 11 shows a typical selection with absolute value signals of carrier signals which is carried out by a receiving signal synthesizing means in Fig 11.

Fig 12 is a block diagram showing the configuration of a communication system in a fifth embodiment of the present invention

Fig 13 is a block diagram showing the configuration of a communication system in a sixth embodiment of the present invention

Fig 14 is a block diagram showing another configuration of a communication system in a sixth embodiment of the present invention

Fig 15 is a block diagram showing a typical configuration of the prior art communication system

Fig 16 shows examples of spectrum waveforms in the prior art sender and receiver.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, the embodiments of the present invention are described with reference to the drawings Figs. 1 to 14

EMBODIMENT 1

Fig 1 is a block diagram showing the configuration of a communication system in a first embodiment of the present invention

In Fig 1, the communication system in a first embodiment of the present invention has a sender 1 and a receiver 2 connected with each other via a transmission line 3

The sender 1 is provided with a sending signal generating means 10

comprising a multiplier 11 and a carrier signal generator 12. The receiver 2 comprises 4 discrete Fourier transformation (DFT) processors 21 to 24 making up a transmission line characteristics measuring means 20, a relative phase detection circuit 25, a selection control means 40 for deciding on the mixing ratio of carrier signals at a receiving signal synthesizing means 30 on the basis of measurement results from the transmission line characteristics measuring means 20, and the receiving signal synthesizing means 30.

In the sender 1, the carrier signal generator 12 generates a plurality of carrier signals with frequencies assuming values at specific intervals and inputs those carrier signals into the multiplier 11. The multiplier 11 multiplies the modulated data, that is, the input data modulated by a modulator (not shown), by the plurality of carrier signals given by the carrier signal generator 12. Those carrier signals are then sent out to the receiver 2 via the transmission line 3.

The carrier signals sent in via the transmission line 3 are then inputted into the four DFT processors in the receiver 2 respectively. Those four DFT processors 21 to 24 have their respective signal zones allocated for the processing of signals. The Fourier transformation of signals in the respective signal zones detects absolute value signals a_1 to a_4 and angular signals b_1 to b_4 which will be described later. The respective absolute value signals a_1 to a_4 detected by the DFT processors 21 to 24 are inputted into the selection control means 40 while the respective angular signals b_1 to b_4 are inputted into the relative phase detection circuit 25.

The relative phase detection circuit 25 detects relative phases from the angular signals b_1 to b_4 and the reference signals and outputs the detected relative phases as relative phase signals f_1 to f_4 to the selection control means 40. The reference signals may be either ones determined in advance or ones given by the sender 1.

The selection control means 40 decides which of the carrier signals to select on the basis of the absolute value signals a_1 to a_4 inputted by the DFT

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processors 21 to 24 and the relative phase signals f_1 to f_4 inputted by the relative phase detection circuit 25, and outputs that selection signal Ss in the next stage, the receiving signal synthesizing means 30. According to the selection signal Ss, the receiving signal synthesizing means 30 synthesizes the selected signals using either the absolute value signals a_1 to a_4 or the angular signals b_1 to b_4 or both. The receive data thus synthesized is demodulated by a demodulator (not shown) to produce a final output data. The type of signals required for the receiving signal synthesizing is decided on according to the modulation formula and other conditions.

The present embodiment is further explained by taking the following case that the modulated data (input signals) inputted into the multiplier 11 in the sender 1 is subjected to phase shift keying (PSK) modulation. It is understood that the spectrum waveform of the modulated data is shown in Fig 2 (a). It is also understood that the carrier signal generator 12 outputs carrier signals for an impulse response of a transfer function $H(\omega)$ given by the following equation (1) and that the impulse waveform of the transfer function $H(\omega)$ is as one shown in Fig 2 (b).

$$H(\omega) = \sum_{k=0}^{3} \delta(\omega - \omega_0 - k\omega_c)$$

$$= \delta(\omega - \omega_0) + \delta(\omega - \omega_0 - \omega_c)$$

$$+ \delta(\omega - \omega_0 - 2\omega_c) + \delta(\omega - \omega_0 - 3\omega_c) \quad \cdots \quad (1)$$

As indicated in the equation (1), the carrier signals outputted from the carrier signal generator 12 are made up of frequencies of four different values at an equal interval (ω_c), that is, frequencies of ω_0, $\omega_0+\omega_c$, $\omega_0+2\omega_c$ and $\omega_0+3\omega_c$. If modulated signals and a plurality of carrier signals are inputted into the multiplier 11, as shown in Fig 2 (c), the multiplier 11 outputs sending signals of each frequency having a spectrum waveform in Fig 2 (a), with the respective carrier signals in Fig 2 (b) as carrier.

Data with four carrier signals is taken up for description of the

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present embodiment. The number of carrier signals is not limited to that, but any number may be selected as necessary.

In the receiver 2, the DFT processors 21 to 24 process the respective carrier signals, that is, pick out absolute value signals a_1 to a_4 and angular signals b_1 to b_4 from the sending signals. Here, the DFT processor 21 processes the carrier signal with a frequency of ω_0; the DFT processor 22, the carrier signal with a frequency of $\omega_0+\omega_c$; the DFT processor 23, the carrier signal with a frequency of $\omega_0+2\omega_c$; and the DFT processor 24, the carrier signal with a frequency of $\omega_0+3\omega_c$. Needless to say, the number of carriers have to tally with that of DFT processors.

The angular signals b_1 to b_4 detected by the respective DFT processors 21 to 24 are inputted into the relative phase detection circuit 25. The relative phase detection circuit 25 in turn detects relative phases for the input angular signals b_1 to b_4 in relation to the reference phases in the respective carrier signals. The relative phases can be found these ways: In case PSK-modulated signals are sent as in this first embodiment, the reference phase is set in advance so that the phase difference between the angle of carrier signal and the reference phase may be found out. In another case where modulated signals by differential phase shift keying (DPSK) modulation formula are sent, the phase difference between the current signal and the one just before that is found

Absolute value signals a_1 to a_4 of the respective carrier signals detected at the DFT processors 21 to 24 and the relative phase signals f_1 to f_4 outputted from the relative phase detection circuit 25 are inputted into the selection control means 40. The selection control means 40 then estimates the transmission line characteristics on the basis of the intensity of input absolute signals a_1 to a_4 and the values of relative phase signals f_1 to f_4 in the way described below and then forms and outputs a suitable selection signal Ss to the receiving signal synthesizing means 30. The receiving signal synthesizing means 30 synthesizes the selected signals on the basis of the

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contents of the selection signal Ss.

Referring to Figs. 3 to 5, there is explained as follows how the line characteristics are determined at the selection control means 40.

There are three determination methods: the first that absolute value signals a_1 to a_4 are to be parameters (Fig 3); the second that relative phase signals f_1 to f_4 are to be as parameters (Fig 4); and the third that both absolute value signals a_1 to a_4 and relative phase signals f_1 to f_4 are to be as parameter (Fig 5).

In the first method using absolute value signals a_1 to a_4 as parameters, it is judged whether there is any distortion in the intensity levels of the absolute value signals a_1 to a_4. For the judgment, a threshold value is set at specific intensity level in advance and it is checked if the absolute value signals a_1 to a_4 are over that threshold value.

If, for example, sending signals are distorted on the transmission line 3 and the absolute value signals a_1 to a_4 of the respective carrier signals detected at the DFT processors 21 to 24 are each attenuated in intensity as shown in Fig 3(a), the signals with the intensity level exceeding the preset threshold value α can be regarded as free from the effect of line distortion. In Fig 3(a), therefore, the carrier signal with a frequency of $\omega_0 + 2\omega_c$ which is under the threshold value α is eliminated while the other carrier signals with frequencies of ω_0, $\omega_0+\omega_c$ and $\omega_0+3\omega_c$ are selected out at the selection control means 40. Those three carrier signals are then synthesized and outputted as detected data.

In the transmission line characteristics that any of carrier signals rises in the intensity level of absolute value because of the narrow band noise as shown in Fig 3 (b), on the other hand, it can be concluded that the carrier signals in lower intensity than the threshold value β are not affected by the narrow band noise. In other words, the true signals received by the receiver 2 can not get higher than those sent out from the sender 1 in intensity, and the signals exceeding that threshold value β must contain some noises. Therefore,

 (3)

the selection control means 40 eliminates the carrier signal with a frequency of $\omega_0+\omega_c$ which exceeds the threshold value β but takes out the carrier signals with frequencies ω_0, $\omega_0+2\omega_c$, and $\omega_0+3\omega_c$. those carrier signals are then synthesized and outputted as detected data by the receiving signal synthesizing means 30.

If a specific value is set as lower threshold value α as in Fig 3(a) and another specific value as upper threshold value β as shown in Fig 3(b), the aforesaid two cases can be coped with.

In the methods using the absolute value signals a_1 to a_4 as parameter which were described above, the selected carrier signals were equally mixed in the synthesizing process. The mixing ratio of individual components may be varied depending on the intensity of signal. The mixing ratio of frequencies of $\omega_0 : \omega_0+\omega_c : \omega_0+3\omega_c$, for example, is to be set at 2:1:3 in Fig 3(a), so that it could produce receiving signals with a high reliability depending on the line characteristics. A threshold value does not necessarily have to be set. Instead, all the receiving signals may be mixed equally. Or the frequencies of $\omega_0 : \omega_0+\omega_c : \omega_0+2\omega_c : \omega_0+3\omega_c$ may be mixed at a ratio of 3 : 2 : 1 : 4 to produce frequency diversity effects.

In the second method in which relative phase signals f_1 to f_4 are used as parameter, it is judged from the relative phase signals f_1 to f_4 whether the signals have been affected by any noise or distortion. This procedure is that the threshold values of the relative phase are set within a range of the relative phase in advance, and it is judged whether the relative phase signals f_1 to f_4 are within the threshold value, that is, within the shaded area in Fig 4. If, for example, sending signals are distorted on the transmission line 3, and the relative phase signals f_1 to f_4 of the respective carrier signals detected at the DFT processors 21 to 24 (indicated with black spots in Fig 4) as shown in Fig 4 indicate the phase shifts, it can be taken that the carrier signals outputting the relative phase signals f_1 to f_4 not exceeding the preset phase range between the threshold values γ_1 and γ_2 are quite free from the

effect of line distortion. In Fig 4, therefore, the selection control means 40 eliminates the carrier signal $\omega_0+2\omega_c$ which is outside the threshold value range between γ_1 and γ_2 and selects out the other carrier signals ω_0, $\omega_0+\omega_c$ and $\omega_0+3\omega_c$. Those three carrier signals are then mixed and outputted as detected data by the receiving signal synthesizing means 30.

When these relative phase signals f_1 to f_4 are used as parameter, too, the mixing ratio of the carrier signals may be varied as in the method using the absolute value signals a_1 to a_4 as parameter.

The third method which uses both the absolute value signals a_1 to a_4 and the relative phase signals f_1 to f_4 as parameter is to find from those two types of signals if a carrier signal is affected by some noise or distortion. That is to say, this method sets both two threshold values α and β of the intensity of the absolute value signals a_1 to a_4 and two threshold values γ_1 and γ_2 or the relative phase range in advance as described above. It is then judged whether the intensity level of absolute values a_1 to a_4 and the relative phase signals f_1 to f_4 are both within the set threshold value range or the shaded area in Fig 5. And the carrier signals which meet the conditions are picked out for synthesis.

In Fig 5, therefore, the selection control means 40 eliminates the carrier signal with a frequency of $\omega_0+3\omega_c$ (marked with a black spot in Fig 5) as off the intensity threshold value range (which is indicated in the distance from the center or intersection point of the threshold values γ_1 and γ_2) and the carrier signal with a frequency of $\omega_0+2\omega_c$ as off the threshold value range of the relative phase signals f_1 to f_4, but picks out the carrier signals with frequencies of ω_0 and $\omega_0+\omega_c$. And those two carrier signals are mixed and outputted as detected data by the receiving signal synthesizing means 30.

As set forth above, the communication system in the first embodiment of the present invention eliminates the receiving signals in a band where the signal power is attenuated with a poor signal to noise ratio (SNR) because of

the line distortion or reduces the mixing ratio of those signals in the synthesizing process, thereby improving the overall SNR. Also, the mixing into data of a plurality of carrier signals from the selection control means can create frequency diversity effects and reduce the influence of narrow band noise.

In the communication system of the first embodiment of the present invention, the DFT processor 21 to 24 detect the absolute value signals a_1 to a_4 and angles of carrier signals. The detection can be effected by narrow band pass filter (BPF) instead of the DFT processors 21 to 24. The first embodiment of the present invention is described using PSK-modulated data. The present embodiment is not limited to that, but can be practiced with amplitude shift keying (ASK) modulated or DPSK modulated data just the same.

Furthermore, it is possible to build a multiplex transmission for a plurality of input data by providing the sender 1 in the system of this first embodiment with a plurality of multipliers 11's and carrier signal generators 12's and a means for synthesizing all the outputs from the plurality of multipliers 11's.

EMBODIMENT 2

Fig. 6 is a block diagram showing the configuration of a communication system as a second embodiment of the present invention.

The selection control means 40 as shown in Fig. 1 can be provided in the sender 1. As illustrated in Fig. 6, the present embodiment is so constituted that the respective outputs from the DFT processors 21 to 24 are fed back to the selection control means 40 provided in the sender 1 via the transmission line 3.

The selection signal Ss of the selection control means 40 sets the carrier signals to be generated at the carrier signal generator 12. Merely selecting the carrier signals to be sent using the absolute value signal a_1 to a_4 on the sender side eliminates the need to do selection again in the receiver

if the selected carrier signals are sufficiently high in reliability. In case no sufficient reliability can be secured, however, it can be configured that the carrier signals are further put to selection using the relative phase signals f_1 to f_4 on the receiver side as indicated in dashed line in Fig 6.

Other possible configurations than that in the present second embodiment are the same as those in the first embodiment. The same reference numbers are used in those configuration, but there will be no detailed description.

It is understood that the modulated data to be inputted into the multiplier 11 in the second embodiment are PSK-modulated ones as shown in Fig 2(a). The carrier signal generator 12 outputs a plurality of carrier signals for impulse response in the transfer function $H(\omega)$ given in equation (2) in which the control action of the selection control means 40 is reflected.

$$H(\omega)=A_1\delta(\omega-\omega_0)+A_2\delta(\omega-\omega_0-\omega_c)$$
$$+A_3\delta(\omega-\omega_0-2\omega_c)+A_4\delta(\omega-\omega_0-3\omega_c) \quad \cdots \quad (2)$$

The parameters A1 to A4 in equation (2) are values based on the absolute value signals a_1 to a_4 for the respective carrier signals fed back from the receiver 2. Therefore, that means that the conditions on the transmission line are incorporated in the parameters A1 to A4.

The initial parameters to be given in this second embodiment are A1 = A2 = A3 = A4 = 1. In this initial state, therefore, the impulse waveform in the transfer function $H(\omega)$ is the same as shown in Fig 2(b) while the sending signals outputted from the multiplier 11 have the spectrum waveform as shown in Fig 2(c).

In the following description of the second embodiment, emphasis is placed on the part of the processing which is different from that in the first embodiment.

As in the first embodiment, the respective DFT processors 21 to 24 on

the receiver side detect the absolute value signals a_1 to a_4 and angular signals b_1 to b_4 in the corresponding carrier signals, and feed back those absolute value signals a_1 to a_4 to the selection control means 40 on the sender side via the transmission line 3 and at the same time inputs the angular signals b_1 to b_4 in the relative phase detection circuit 25.

Receiving the absolute value signals a_1 to a_4 in the respective carrier signals, the selection control means 40 determines the intensity of those signals and generates parameters A1 to A4 on the basis of that intensity.

To be concrete, in case the absolute value signals a_1 to a_4 in the corresponding carrier signals fed back from the receiver 2 are each attenuated in intensity because of such factors as line distortion, the selection control means 40 so controls the carrier signal generator 12 as to bring to "0" the parameters A2 and A3 for the carrier signals with frequencies of $\omega_0+\omega_c$ and $\omega_0+2\omega_c$ under the threshold α and to turn to "1" the parameters A1 and A4 for the carrier signals with frequencies of ω_0 and $\omega_0+3\omega_c$. Through that control action, the impulse response of the transfer function $H(\omega)$ from the carrier signal generator 12 is made as shown in Fig. 7(b). After that control action, therefore, the signals sent out from the multiplier 11 will take a spectrum waveform as shown in Fig. 7(c). That permits transmission of data avoiding the carrier signals having line distortion.

As set forth above, the second embodiment of the present invention feeds back the absolute value signals with the line characteristics incorporated in them to the sender 1 from the receiver 2. Using those absolute value signals a_1 to a_4, the sender 1 is so controlled as not to send data in a band where the signal power is attenuated with SNR deteriorated because of line distortion. Thus, the sending signals as a whole are improved in SNR.

The description has been made of the operation in which the lower threshold value α is used. The description is applicable both where the upper threshold value β is used and where the two threshold values are used.

In the second embodiment of the present invention, the absolute value signals a_1 to a_4 for the corresponding carrier signals are used to control the carrier signals by feeding back those absolute value signals to the selection control means 40. The same results can be obtained by using the relative phase signals f_1 to f_4 for the respective carrier signals instead. Also, use of both the absolute value signals a_1 to a_4 and the relative phase signals f_1 to f_4, needless to say, produces the same results.

In the second embodiment, the parameters for the absolute value signals a_1 to a_4 under the threshold value are set to "0". The parameters may be fixed according to the absolute value signals a_1 to a_4, for example, A1 = 1.2, A2 = 0.5, A3 = 0.5, A4 = 1.2.

Furthermore, in case the selection control means 40, provided on the sender side, uses the absolute value signals a_1 to a_4, the selection control means 40' on the receiver side may use the relative phase signals f_1 to f_4 to subject the carrier signals to selection control.

EMBODIMENT 3

Fig. 8 is a block diagram showing the configuration of a communication system as a third embodiment of the present invention.

As a comparison between Fig. 6 and Fig. 8 shows, the third embodiment is different from the second embodiment in that the selection control means 40 is provided in the receiver 2 instead of the sender 1. Other than that, the two embodiments are identical in configuration, and no explanation is made of the configuration of the third embodiment.

As mentioned above, the communication system of the third embodiment of the present invention has the selection control means 40 on the receiver side so as to feed back to the sender the signals or parameters to control the carrier signal generating means 12. Therefore, the third embodiment has the same features as the second embodiment of the present invention and makes it easy to build the feedback transmission line 3.

EMBODIMENT 4

Fig 9 is a block diagram showing the configuration of a communication system as a fourth embodiment of the present invention

As shown in Fig 9, the sender 1 and the receiver 2 are connected to each other via the transmission line 3 running from the sender 1 to the receiver 2 and via a transmission line 6 running from the receiver to the sender 1.

The sender 1 comprises two multipliers 11a and 11b, two carrier signal generators 12a and 12b, two selection control means 40a and 40b and a sending signal synthesizer 14. The receiver 2 is equipped with four DFT processors 21 to 24, a relative phase detection circuit 25 and a receiving signal synthesizing means 30.

As a comparison between Fig 6 and Fig 9 shows, the fourth embodiment is different from the second embodiment in that the sender 1 in the present embodiment is provided with two sets of the sender of the second embodiment and a sending signal synthesizer 14. The receiver 2 of the fourth embodiment is basically the same as the receiver 2 in the second embodiment, but the receiving signal synthesizing means 30 of the fourth embodiment outputs as many detected data as the modulated data input in the receiver 2 (input data of the sender 1). Other than that, the two embodiments are identical in configuration, and common reference numbers are used, and there is no detailed description of the configuration of the present embodiment.

The absolute value signals a_1 to a_4 for the respective carrier signals from the DFT processors 21 to 24 in the receiver 2 are input into the selection control means 40a and 40b. The selection control means 40a and 40b control the respective carrier signal generators 12a and 12b on the basis of those absolute value signals a_1 to a_4. According to those carrier signals, the carrier signal generators 12a and 12b generate and input carrier signals in the multipliers 11a and 11b.

The multiplier 11a multiplies the respective carrier signals inputted by the carrier signal generator 12a and the first modulated data together and outputs the results. The multiplier 11b multiplies the respective carrier signals inputted by the carrier signal generator 12b and the second modulated data together and outputs the results. Furthermore, the sending signal synthesizer 14 synthesizes the outputs from the multipliers 11a and 11b and outputs the results to the transmission line 3.

As set forth above, the fourth embodiment, which is equipped with two units of the receiver used in the second embodiment, has a plurality of carrier signals assigned for each of two different modulated signals (input signals) so that the respective carrier signals may be modulated with the two input data and sent out simultaneously. In the following description, a total of four carrier signals are assigned on the assumption that the present embodiment is configured on the same circuit scale as the first and second embodiments. To make the transmission quality as good as that of the other embodiments, however, it is desirable to allot four carrier signals for each of the two different modulated data.

It should also be noted that the modulated data to input are not limited to two. Still more inputs can be dealt with if there are provided as many multipliers, carrier signal generators and selection control means as the number of modulated data to input.

In the fourth embodiment, it is understood that the first modulated data to input in the multiplier 11a is a PSK modulated data shown in Fig. 10(a) and the second modulated data to input in the multiplier 11b is a PSK modulated data shown in Fig. 10(b). Also, the carrier signal generator 12a outputs a plurality of carrier signals for the impulse response of a transfer function Ha(ω) given in equation (3) in which the control action of the selection control means 40a is incorporated. The carrier signal generator 12b outputs a plurality of carrier signals for the impulse response of a transfer function Hb(ω) given in equation (4) in which the control action of the selection control

means 40b is incorporated

$$Ha(\omega) = A_1\delta\ (\omega - \omega_0) + A_2\delta\ (\omega - \omega_0 - \omega_c)$$
$$+ A_3\delta\ (\omega - \omega_0 - 2\omega_c) + A_4\delta\ (\omega - \omega_0 - 3\omega_c) \quad \cdots \quad (3)$$

$$Hb(\omega) = A_1\delta\ (\omega - \omega_0) + A_2\delta\ (\omega - \omega_0 - \omega_c)$$
$$+ A_3\delta\ (\omega - \omega_0 - 2\omega_c) + A_4\delta\ (\omega - \omega_0 - 3\omega_c) \quad \cdots \quad (4)$$

A1 to A4 and B1 to B4 in the equations are parameters obtained on the basis of the absolute value signals a_1 to a_4 fed back from the receiver 2. In the fourth embodiment, the parameters set in the carrier signal generator 12a are defined as A1 = A2 = 1 and A3 = A4 = 0. The parameters set in the carrier signal generator 12b are defined as B3 = B4 = 1 and B1 = B2 = 0.

In this initial stage, therefore, the impulse waveforms (carrier signals) of transfer functions Ha(ω) and Hb(ω) are as shown in Fig 10 (c) and Fig 10(d) respectively. The sending signals, the output of the sending signal synthesizer 14, takes a spectrum waveform as shown in Fig 10(e).

Now, the operation of the fourth embodiment is explained in more detail with emphasis on where the present embodiment is different from the first and second embodiments.

The respective DFT processors 21 to 24 detects the absolute value signals a_1 to a_4 and angular signals b_1 to b_4 in the corresponding carrier signals as in the second embodiment. Those absolute value signals a_1 to a_4 are then fed back to the selection control means 40a and 40b via the transmission line 3 and at the same time outputs the angular signals b_1 to b_4 to the relative phase detection circuit 25.

Receiving feedback of the absolute value signals a_1 to a_4, the selection control means 40a judges the intensity of the first modulated data and controls the parameters A1 to A4 on the basis of the judgment results. The selection control means 40b to which the absolute value signals a_1 to a_4 judges

the intensity of the second modulated data and controls the parameters B1 to B4 on the basis of the judgment results.

In principle, those selection control means 40a and 40b do the same selection of the absolute value signals a_1 to a_4 as the selection control means 40 in the first embodiment. For example, in case the absolute value signals a_1 to a_4 for the corresponding carrier signals are attenuated in intensity to varying degrees because of such factors as line distortion as shown in Fig 11 (a), the selection control 40a so controls the carrier signal generator 12a as to bring to "0" the parameter A2 for the carrier signals with frequencies of $\omega_0+\omega_c$ under the threshold value along with the parameters for A3 and A4. And the selection control 40b so controls the carrier signal generator 12b as to bring to "0" all the parameters B2, B3 and B4 for the carrier signals with frequencies of $\omega_0+2\omega_c$ below the threshold value. In Fig 11, the signal intensity of the first modulated data is indicated by blank arrow while the signal intensity of the second modulated data is indicated by shaded arrow. Through that control action, the signals to be send from the sending signal synthesizer 14 takes spectrum forms as shown in Fig 11 (b). Thus two information signals can be sent with the carrier signals affected by line distortion eliminated.

Furthermore, if the parameters A1 and A2 are set to "0" and the parameters B1 and B2 to "1" in the first carrier signal generator 12a, then the carrier signal $\omega_0+3\omega_c$ will be loaded with the first modulated data, and not the second one, as shown in Fig 11 (c). In this case, only the first modulated data can be sent, but the frequency diversity effects reduce the influence on the first modulated data of narrow band noise.

As shown, the communication system in the fourth embodiment of the present invention permits transmission of high quality data with improved SNR when a plurality of independent data are sent, that is, multiplexed, or a plurality of data is transmitted divided in carrier signals at a high speed. That is effected through provision of the aforesaid arrangement for each data

and feedback of line characteristics from the receiver 2 to the sender 1 so that if a band is found where the signal power is attenuated because of line distortion with deteriorated SNR, the number of multiplex data signals or data rate may be reduced.

In the fourth embodiment as in second embodiment, the absolute value signals a_1 to a_4 are fed back from the selection control means 40a and 40b and used as signals to control the carrier signals. The relative phase signals may be used instead to achieve the same results.

Also, it is configured in the fourth embodiment that the parameter for a carrier signal below a set threshold value is set to "0" so as not to use that signal. Instead, the parameters may be so controlled as to vary the mixing ratio of the respective carrier signals.

The description has been made of the operation in which the lower threshold value is used. Needless to say, the description is applicable where the upper threshold value is used or where the two threshold values are used. Also, the relative phase signals f_1 to f_4 to indicate the phases within a specific range may be used in combination, of course.

Furthermore, still higher quality data transmission is possible through provision of the selection control means 40' on the receiver side to do additional selection side by side by utilizing the output of the relative phase detection circuit 25.

EMBODIMENT 5

Fig. 12 is a block diagram showing the configuration of a communication system as a fifth embodiment of the present invention.

As shown in Fig. 12, the fifth embodiment is different from the fourth embodiment in that the selection control means 13a and 13b are formed in the receiver 2 instead of the sender 1. Other than that, the two embodiments are identical, and no description will be made of the configuration of the fifth embodiment.

As mentioned, the selection control means 40a and 40b are incorporated in the receiver so as to feed back to the sender 1 the parameter signals to control the carrier signal generators 12a and 12b. That simplifies the formation of the feedback transmission line 6 in addition to bring about the same features as presented in the fourth embodiment.

EMBODIMENT 6

In the foregoing embodiments, the input signals and carrier signals are multiplied together. It is possible to pick out the carrier signal directly from the input signals using filters. In this sixth embodiment, still better results can be achieved by merely passing the input signals through a plurality of filters having central frequencies on the axis of frequency at a specific interval so as to extract carrier signals free from interfering with each other on the axis of frequency (hereinafter called orthogonal signal) and free from interfering between one frequency and the preceding or following frequency on the axis of time (in this case, too, called orthogonal signal).

Figs. 13 and 14 show basic configurations of communication systems using double orthogonal carrier signals which are orthogonal both on the axis of frequency and the axis of time. The input signals are input in an encoder 50 in the sender 1 and divided in the number corresponding to that of filters 52a to 52d in the next step. For purpose of simplification and better understanding, the input signals shall be digital and named "1". But it goes without saying that modulated signals may be used as in the preceding embodiments 1 to 5.

The signals thus generated are upsampled by upsampling means 51a to 51d into a plurality of signals within the same bit rate. to be concrete, a plurality (M-1) of "0"'s are inserted behind the input "1". The number of "0" to be inserted is not limited. If three "0"'s (that is, M=4) are inserted, the time of "1" in one bit rate is shortened to 1/4. The time of "1" in one bit decreases with increasing number of "0"'s inserted. As will be described, the

larger the number of "0"'s, the less the effect of noise.

The upsampling is to shorten the diffusion interval of input signals on the time axis. That is effective, on the frequency axis, in scattering the input signals in a narrow band over a wide range from a low frequency band to a high frequency band and is equivalent to the step of converting the input signals into high frequency carrier signals as in the multiplication in the other foregoing embodiments.

The input signals thus upsampled are inputted in a plurality (in this case, 4) of filters 52a to 52d of which the central frequencies assume values at a specific interval. Here, the impulse response to the respective samples on the filters in the sender can be given as follows:

$$f_i(n), \{i=1, 2, ..M\} \quad \cdots (10)$$

and if the filter design conditions are as follows:

$$\sum_{n=0}^{j-1} f_{i1}(n), f_{i2}(n-jM) = A\delta(j)\delta(i_1-i_2) \quad \cdots (11)$$

where

L: number of taps of filters

i_1, i_2: suffixes indicating carrier signals

j: duplication coefficient

M: number of samples per data bit

A: integral number > 0

δ: delta function

then filters can be obtained which satisfy the orthogonal requirements both on the time axis and the frequency axis. The equation (11) will have a value when j = 0, that is, when there is no sample duplication, or $i_1 = i_2$, that is, when

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a carrier signal is not duplicated by another frequency carrier signal. In any other case, the equation will be "0", with the formation of a carrier signal infinitesimal both on time axis and frequency axis.

The outputs from the filters 52a to 52d thus designed are synthesized by the synthesizing means 53 and sent out on the transmission line. Thus, the sending signals are turned into carrier signals with frequencies at certain intervals.

The sending signals thus sent out are inputted into filters 62a to 62d provided in the receiver 2 which are equal in number to the filters 52a to 52d in the sender 1 that also correspond to those filters in central frequency. Here, the impulse response to samples on the filters in the receiver 2 can be expressed as follows:

$$h_i(n), \{i=1, 2, .. M\} \quad \cdots (21)$$

and the filters are designed to conform to the following conditions:

$$h_i(z) = z^{-(I-1)} F_i(z^{-1}) \quad \cdots (22)$$

In other words, the filters are so designed that the outputs from filters 62a to 62d are identical with the inputs of the filters 52a to 52d but are delayed on the axis of time, and then the filters 62a to 62d meet the following orthogonal requirements:

$$\sum_{n=0}^{J-1} h_{i1}(n), h_{i2}(n-jM) = A\,\delta(j)\,\delta(i_1-i_2) \quad \cdots (22)$$

Thus, any noise that arises will not affect the output as long as it is not identical with the filters 62a to 62d in central frequency and on the

axis of time (in the above case, the first 1/4 of one bit rate).

The outputs of the filters 62a to 62d in the receiver 2 are inputted in the down-sampling means 61a to 61d. Data is eliminated which corresponds to the samples added by the up-sampling means 51a to 51d at the time of sending and then the signals required for synthesis are inputted in a decoder 60, a receiving signal synthesizing means. The required signals are angular signals, absolute value signals or the very real signals outputted by the down-sampling means 61a to 61d.

Meanwhile, the outputs of the down-sampling means 61a to 61d are led to a conversion means 70 which detects the absolute value signals a_1 to a_4 and angular signals b_1 to b_4. There, the absolute value and angle of each frequency component in the sending signals are detected as the DFT processors 21 to 24 do in the previous embodiments 1 to 5. Those angular signals b_1 to b_4 are further inputted in the relative phase detection means 25 to detect the relative phase. Here, both or either of the absolute value signals a_1 to a_4 and relative phase signals f_1 to f_4 thus detected are inputted in the selection control means 40 provided in the sender 1 or the receiver 2 and are used to control the sending signals or receiving signals the same way as described in the previous embodiments 1 to 5.

In the example shown in Fig. 13, the absolute value signals a_1 to a_4 and the relative phase signals f_1 to f_4 are both used and involved in selection at the signal section means 40 or decision on the mixing ratio. The decoder does decoding on the basis of those results.

The example illustrated in Fig. 14 feeds back the absolute value signals a_1 to a_4 from the conversion means 70 to the encoder 50 in the sender 1, which then selects carrier signals or decides on the mixing ratio of the carrier signals. In this case, too, it goes without saying that it is possible to use the relative phase signals f_1 to f_4 from the relative phase detection means 25 on the receiver side as well and further put those signals to selection control.